THE INVESTIGATION OF TRAFFIC POSSIBILITIES OF PROPOSED SUBWAY LINES

By William S. Twining,
Of Ford, Bacon & Davis, Consulting Engineers, New York.

The investigation of traffic possibilities of proposed subway lines is one phase of the general problem of determining the traffic possibilities of any transportation system that may be built over or under city streets, or on private right of way without grade crossing. These lines may properly be designated as Rapid Transit Systems.

If we study what has been done in large cities in the last thirty-five years, we obtain considerable data and assistance, as lines of this character have been built here and abroad in the following cities, beginning with New York City about 1878:

Elevated Roads.—New York City, Brooklyn, Chicago, Boston, Philadelphia, Berlin, Paris, Liverpool.

Subways.—Boston, New York (Manhattan), Brooklyn, Philadelphia, Berlin, Paris, London, Budapest.

Each city appears to present its own peculiar problems, due to the difference in city plan, relative location of business and residential districts, and other purely local conditions.

With the exception of the Boston and New York subways all these American rapid transit lines have been built by private capital as business ventures, and as the greater number were built with the idea of creating or building up traffic they had very little financial success for many years, several of them suffering from lack of sufficient patronage to produce net earnings sufficient to pay interest on their cost, and passing through receivers' hands.

The earlier rapid transit lines were operated by steam locomotives, but the substitution of electric motors began between 1893 and 1895, and as all are now electrically operated, reference will be made to no other method.

Compared with elevated railroads, subways have real advantages and disadvantages, as follows:

Advantages	*Disadvantages*
No obstruction in street.	Greater interference with business during construction.
Larger platform space.	Much higher cost of construction.
Less stair climbing.	Artificial lighting.
Less noise on street.	Difficulty in waterproofing and taking care of drainage; also of properly cooling or ventilating.

The reason for any study of a proposed project of this kind is, of course, primarily to determine its commercial feasibility, since if built with private capital the most important questions to be answered are:

(1) Will it pay from the start its operating expenses and a fair return on its total cost?

(2) If not from the start, how soon will it reach a satisfactory income basis, and what will the losses have been in the meantime?

(3) What will the greatest profit be when the line reaches its full carrying capacity?

While these questions involve a preliminary estimate of the cost of the proposed route, it will be readily seen that the most important factor to be correctly estimated is the amount of the income, since if this can be approximately foretold, it determines the feasibility of any project.

Under equal conditions, with the same type of equipment and the same number of stops per mile, the traffic capacity, and therefore the income of the different rapid transit systems, should be approximately the same. That is, as a transportation machine a subway has no greater efficiency than an elevated road or a road on private right of way.

As the operating expenses under equal conditions are approximately the same for each type, the net earnings should be the same, and from the above it will be clear that the type of railway having the lowest total cost of construction should be the most profitable.

Rapid transit systems are usually intended purely for passenger transportation. Hence the first data to be obtained relates to the probable number of passengers per annum that will patronize the line when opened; Second, What will be the probable increase in business or travel each year for, say, five years? Assuming the

fare will remain at the now customary amount—five cents—the income can be, of course, readily known, and this will be distributed as follows:

Operation and maintenance.

Taxes and municipal charges.

Interest on investment.

Depreciation or its equivalent should be allowed for as soon as the line reaches a paying basis.

Since these lines usually follow an earlier built surface street car line, from its earnings an estimate of the income can usually be made by assuming

(1) That it will take a certain period of time, say three years, to build the rapid transit line, and this allowance for growth should be added to the present income of the surface lines. This growth is usually stimulated by the prospect of better transit facilities and is, consequently, greater than the normal rate.

(2) That a large percentage of the surface car lines long riders and a small percentage of the short riders will be diverted to the quicker route.

(3) That cross-town lines of surface cars will furnish quite a large business, particularly if an arrangement for interchange of passengers can be made. This brings up the subject of transfers, which will not be enlarged upon here.

(4) If in competition with steam railroads some traffic will be obtained if better or more frequent service is rendered. Right here it may be said that while lines of this class do not cater to so-called "pleasure riders," the provision of comfortable cars and clean, quick and frequent service will have a marked effect in the number of riders, and consequently in the income.

No general rules for making these estimates can be given. It is a case calling for the exercise of caution and judgment by the engineer who makes the estimates and the promoter who finances the project. Herein lies the large business risk, and the writer believes that inasmuch as the growth of large cities demands the supply of some quicker form of transportation than is afforded by street cars, the city itself should construct the tunnels or elevated structures which represent a large part of the investment, leaving the same to be operated by a transportation company.

The reasons for favoring this solution are as follows:

(1) The great benefit is to those citizens who are able to patronize it.

(2) As the value of real estate for business or residential purposes is in direct proportion to the transportation facilities, the property benefited should pay directly or indirectly for part or all of these facilities. Transportation in a large city is as much one of the necessities of life as city water or sewers, and these tunnels or elevated structures are simply an extension of the street area vertically instead of horizontally, which would involve widening with its consequent property damage account.

(3) If built to take care of the "long haul" passengers the outer ends of such lines will usually be unprofitable, for these outer sections are comparatively thinly populated. It is to the interest of the operating company to make these lines as short as will develop sufficient traffic for their support, since a line five miles long will earn much more per mile per car than one ten miles long, and the total investment will only be approximately one-half as much. From the standpoint of the municipality it is desirable to reach and develop parts of the city or country beyond the field of the surface street cars.

(4) The cost of roads of this character is such that if built by private capital their construction in the future will be delayed until it is reasonably certain that they will pay interest on their cost, thereby following the population instead of leading it and developing the city's growth.

(5) In the case of subways, particularly, it is always necessary to build them so as to provide for future growth, since they can be enlarged only with great difficulty and expense. This means a much larger and more expensive structure than is needed at the start, thereby increasing the interest charges at a time when the earnings are smallest and the operating expenses are highest. Also, since these lines are usually built on main thoroughfares and will form, in the down-town district, a valuable extension of street area, it is to the city's interest when such a system is built that it shall utilize the full carrying capacity of the street. That is, a street in every way suitable for a four-track subway and in a district where four tracks will ultimately be necessary, should not be sacrificed to the present needs by allowing, say, a one- or two-track structure to be built in it.

(6) As these lines are vital to the health, wealth and general prosperity of modern large cities, there is good reason for claiming for them the same assistance and support as has frequently been extended to the undertakings of undoubted public benefit although working under private charter—as for example, the subsidizing of steamship lines, etc.

For locations where the traffic is so great as to demand more than two tracks, the subway is more suitable from the standpoint of the municipality, as a three- or four-track elevated structure is decidedly objectionable unless in a very wide street. Moreover, if the traffic is greater than two tracks can carry, the density of population is probably sufficient to warrant the more expensive subway structure.

Of course, under certain conditions, a promoter may not be free to adopt the type of transportation system which promises the greatest net profits, since in many cities there is a strong prejudice against elevated railways and equally strong sentiment favoring subways for local rapid transit systems. This dislike of elevated roads is well founded when applied to the earlier designs, such as exist in New York City. The modern designs, using heavy ballasted floors, are almost entirely free from the objections raised against the original open-deck type of construction.

As to the relative cost per mile of double-track railway or structure, it is of course difficult to make any close comparison, as local conditions affect costs, particularly of subways, to a very large extent; but the following may be assumed as a fair range of probable costs:

	Per mile of route–double track	
	Lowest cost.	Average cost.
Surface line (trolley)	$30,000	$50,000
Open floor elevated	300,000	400,000
Solid " "	550,000	700,000
Subways	2,000,000	4,000,000

As lines on private right of way involve the purchase of large amounts of real estate, no general range of probable costs can be given. The figure of $4,000,000 given above for cost of one mile of subway construction may even be exceeded in special cases, as in the Washington Street Subway in Boston, one of the most difficult and expensive pieces of work, considering its length, that has been built for a rapid transit system.

City surface street cars can not usually be classed among rapid transit systems on account of being limited to low average speed by their frequent stops.

The carrying capacity per hour in one direction of any transportation system is the product of the carrying capacity per car multiplied by the number of cars per hour passing a fixed point.

The maximum capacity for a double track line of surface cars, without overcrowding, is probably about 80 passengers per car $\times$ 150 cars per hour = 12,000 passengers in one direction. While for a modern rapid transit line running ten-car trains on one minute headway, we may take 100 passengers per car $\times$ 10 cars per train $\times$ 60 trains per hour = 60,000; or, say, five times the capacity of a surface line. This is passenger capacity. However, since the schedule speed of the rapid transit line should be about double that of surface cars, the comparative maximum work done by the railroads per hour is as one to ten, that is, five times the number of passengers carried twice the distance. Starting thus with the maximum carrying capacity, the "load factor" or ratio of average travel to maximum travel must be estimated. The daily period of maximum travel on all city transportation lines will average, say, two hours each in the morning and evening, a total of four hours, with fourteen hours of light travel and six hours with little or none.

As an example, take the Market Street Subway in Philadelphia. From the last (1910) report, we learn that this road, with a length of seven and one-half miles between terminals earned, in round numbers, $1,500,000 and ran 4,258,000 car miles; thus earning about thirty-four cents per car mile. The maximum service at present supplied during the rush period consists of five-car trains on two and one-half minute headway, twenty-four trains per hour equals 120 cars per hour past any station.

Four million two hundred and fifty-eight thousand car miles per year on an eighteen-hour basis on this particular road is equivalent to an average of forty-three cars per hour past any station, a load factor of about thirty-six per cent or thirty-nine cars on the basis of twenty hours operation (thirty per cent).

This proportion will vary in different cities, depending on the character of the territory served, the quality of service and the amount of competition. It is interesting to note, in the case above, that while the rapid transit line earns thirty-four cents per car mile,

the surface car line which parallels it earns twenty-six cents per car mile, showing that each grade of transportation fills a need and one supplements the other.

If we assume the minimum total cost of a double track subway railroad, including equipment at the low figure of $2,000,000 per mile, it is clear that it must earn at least about as follows to be commercially successful:

Interest 6 per cent	$120,000
Operation and taxes (50 per cent of gross earnings)	120,000
Total	$240,000

or at five cents fare, 4,800,000 passengers per mile of route per annum.

Should local conditions make the total cost higher than $2,000,000 per mile, or should the operating expenses and taxes exceed fifty per cent of the earnings the interest item would have to be reduced or the traffic increased.

The Market Street Elevated in Philadelphia by its last (1910) report carried about 30,000,000 passengers on seven and one-half miles of route, or 4,000,000 per mile. The elevated roads of New York city carried last year about 7,500,000 passengers per mile of route and the subways about 10,000,000, part of the latter route being four-track.

In only one of the American cities (Boston) has an entire subway been built to form a down-town terminal for surface street cars, although a part of the Philadelphia subway was so designed. It is the writer's belief that short sections of subways in the congested district, for use by surface cars, will prove a solution for the "rush hour problem" in the large eastern cities where the streets are narrow and the business section confined to a limited area. This solution has much to recommend it, the strongest argument being the comparatively low expenditure for the advantages gained, and the structure being built in the terminal district may form part of a true rapid transit line when the growth of the city outruns the carrying capacity of surface cars.

A second argument results from the fact that on few lines in the residential sections of a city is a shorter "headway" between cars than two minutes warranted even during "rush" periods; this

would permit, let us say, four to six surface car lines from different parts of one district to be brought into one subway and thereby serve a much larger population than one rapid transit line *based on equal time of trip,* and at much lower cost, owing to much of the route being served by the lower cost surface car equipment. Of course, the subway portion will not be worked so efficiently as when used for train operation, handling, say, 120 cars per hour in single units instead of, say, 500 per hour with train operation; but these facts should be taken into consideration:

(1) That a subway when built must always have a capacity largely in excess of the traffic intended for it at the time of construction, in order to allow for growth.

(2) As they are only built in congested districts, they really form city terminals and reduce delays from obstructions and interference on the street, thereby permitting higher schedule speeds for which considerable outlay is warranted.

(3) The outlay is made as the business and traffic require; that is, the addition of the subway terminals to the surface lines permits them to be operated to their full capacity, and when this is reached, the rapid transit line can be completed and train equipment added as needed.

(4) A rapid transit line operated independently of the surface lines usually serves only a comparatively narrow territory lying along each side of it—say not over 1,500 feet as an average, or it must draw the bulk of its traffic from an area of 300 to 400 acres per mile of route. If operated in connection with surface lines, this area will be much increased, but it introduces the transfer problem, which should always be avoided when possible, and involves change of cars, also objectionable and tending to reduce traffic. The proposed plan allows "through routing" and avoids the objectionable features mentioned above.

The writer believes that each type of road has its own proper field.

The subway or tunnel system is particularly well adapted for use in the down-town or business district. Here it performs the function of a terminal, and the high construction cost is partly offset by the saving in property damages which would result from any other form of construction. In a congested business district the columns of an elevated structure are decidedly objectionable,

whether they are located on the curb line or in the street pavement, and the elevated stations with the long platforms needed to accommodate the eight- or ten-car trains are not things of beauty as ordinarily designed. These platforms, to accommodate ten-car trains, should be not less than 450 feet long, and with stations one-half mile (2,640 feet) apart, seventeen per cent of the total length of line would be station platforms.

In the outer sections of cities, while the subway system may be preferable from the standpoint of appearance and freedom from noise, the less expensive elevated type of structure is the more advisable on account of the comparatively limited amount of traffic. Considered as a transportation tool, the theory of efficiency demands that for rapid transit systems the total cost for interest and operation and maintenance shall be the lowest possible. Assuming that the items for operation and maintenance would be the same for subway and elevated roads under equal conditions, it is clear that the cheapest form of construction which will do the work should be used, as this will make the total cost of carrying a passenger the minimum, and with a fixed rate of fare, should leave a maximum of profit.

The expression, "cheapest form of construction," is used in an engineering sense, and means that in making comparative estimates of the cost of these systems only the real essential features need be included. All expenses for ornamentation or decoration, where it involves extra cost, should be estimated separately. While not advocating the lavish use of ornamental features, the writer believes that elevated railways, particularly, can be made less objectionable to the public by proper and careful design.

Finally, the writer would earnestly urge the transportation committees in our large cities to have a complete unbiased engineering study made of all their local needs and conditions before deciding to recommend franchises for any particular rapid transit route, whether subway or elevated, as the transportation of our cities should be developed as a whole and along a definite and determined plan.